AUTOMOTO-
Automated Driving on Motorways
Study of Infrastructure Support and Classification for Automated Driving on Finnish Motorways

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AUTOMOTO – aims of the study

Assess the **feasibility of the selected motorway** section (Highway E12 between Helsinki and Tampere) for the operation of SAE Level 3 and 4 automated vehicles.

Propose a way to **classify Finnish road network from the automated vehicles operations' point of view**, i.e. propose a framework for service level classification for automated vehicles.

Prepare a **proposal for further actions** in research and development work, follow-up and international cooperation

The final report & annexes:

https://www.doria.fi/handle/10024/182620

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SCOPE OF THE FEASIBILITY ASSESSMENT

- Focused on the road attributes that have effect on the Operational Design Domain (ODD) for SAE L3 and L4 automated vehicles

- Inventory contained both analysis of data from the databases as well as field measurements regarding the following areas:
  - **Data & services inventory:**
    - Physical infrastructure and the static & dynamic features based on an ODD classification
    - Typical weather conditions (road weather station data)
    - Availability of traffic information services
  - **Field measurements & data gathering:**
    - Commercial mobile network capability (three operators - 4G, 5G)
    - GNNS positioning & correction services (GPS, Galileo, Glonass)
    - Rut depths, road marking condition (Mobileye)
    - Data gathering: 3D pointcloud, 360^{o} images, HD map elements

FINDINGS FROM THE FEASIBILITY ASSESSMENT

Physical road features

- Used design requirements on motorways are likely to be sufficient for level 3 and 4 automated vehicles
- Space for Minimal Risk Movement (MRM) on the right shoulder is sufficient (3 m or more)
- Road maintenance standards are good enough (summer)

Road condition

- Less than 2% of lane length had rut depths exceeding the set limit of 20 mm for automated driving
- Mobileye recognised > 99% of road markings reliably
    - However, due to winter conditions and snowfall, there will be recurrent periods, when the lane markings are totally covered with snow/slush

Traffic management & information services

- The current traffic management systems in the test section provide useful data support for AVs
- Detours are not instrumented with TM devices
- A variety of public and private information services for human drivers are available providing relevant information regarding weather and traffic conditions
- No ETSI C-ITS services

FINDINGS FROM THE FEASIBILITY ASSESSMENT

Communication networks

- Mobile network up/down speed rates vary between 1-500 Mbit/s along the road. On average 5..15 Mbit/s, latency 50..100 ms
- Existing fixed network & passive infrastructure is on a good level in the proximity of the test section, which means decreasing cost estimates for the possible future investments

Positioning

- GNSS-based positioning accuracy is on cm level 83 % and at least dm level 96 % of the time (using all satellite constellations & with correction service(s)
- SNR > 40 dB almost everywhere

Weather conditions

- In the autumn months (September-November), difficult weather conditions for AVs exist on average 25 hours/month (3.5% of time), mainly due to formation of fog
- In the winter months (December-February) difficult conditions exist on average 35 hours/month (5% of time), dominant reason being the formation of icy road surface

DEVELOPMENT NEEDS IDENTIFIED IN THE FEASIBILITY ASSESSMENT

- The future recommendation of the MRM policy needs to be formed in close cooperation with automotive industry and following international standards
- Another future concern regarding the design principles of motorways is the possible need for specific areas for coupling and uncoupling of truck platoons.
- To provide full support, the current traffic management systems should support C-ITS communications standards. Also the accuracy of information service content needs to be improved to be sufficient for AVs, and to meet the agreed ETSI C-ITS standard requirements.
- Regarding positioning, in case the GNSS signal strength falls for a longer period of time (in conjunction with e.g. tunnels), positioning can be managed with other technologies. Specific landmark structures may be deployed on the most problematic sections.
- For telecommunication services the most demanding use cases, namely cooperative driving and tele-operated driving, require at minimum 100 Mbit/s capacity in both directions, and some of them also an end-to-end latency below 10ms. Such speeds are currently supported only in the proximity of largest urban areas.
- The automated vehicles, and their users, could be provided with accurate information and prediction of critical weather conditions to enable them to make preparations for timely take-overs or MRMs.

SERVICE LEVEL CLASSIFICATION

"The proposed classification was developed to be transferable to motorways everywhere, at least in Europe."

- The classification utilised the ISAD (Infrastructure Support for Automated Driving) levels (Lytrivis et al. 2019) as its starting point
- Over 100 ODD attributes were classified from E to A
- According to the E12 case study, the Finnish motorways are likely corresponding quite nicely to the proposed classification, with most sections **reaching level D** and many **even level C** at least with regard to selected individual attributes
- Please see separate paper #152 "Classification of Physical, Digital, and Operational Road Infrastructure Support for Automated Driving on Motorways" by Risto Kulmala and Satu Innamaa (TP 19, Tue 31.05.)

Attribute classes
- Physical infrastructure
- Digital infrastructure
- Environmental conditions
- Dynamic elements

Levels of service
- E: Conventional (physical) infrastructure only, no AV support
- D: Static digital information / map support
- C: Dynamic digital information
- B: Cooperative perception
- A: Cooperative driving

Table 12. ISAD levels on the E12 road sections from Tampere (road section 135) to Ring road III (103). ** denotes attributes not checked via field studies.*

Road section ISAD attribute	103	104	106	108	109	111	112	113	115	116	117	118	120	121	122	123	124	125	126	134	135
Lane marking retro-reflectivity	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Luminance contrast ratio *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Lane marking consistency	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Bearing capacity of lane *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Shoulder width	C/E	C	C	C	C	C/E	E	E	E	E/C	C	C	C	C	C	C	C	C	C	C	C
Shoulder bearing capacity *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Widening or lay-by	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E
Drivable area sign *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Induced road surface condition	<E	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	<E	D
Landmarks (here: lighting poles	C	D	D/C	D/C	D	D	D	D/C	D	C	D/C	D	D	D	D	D/C	D/C	D/C	D/C	D/C	C
Construction site detour *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Road works *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Communication cellular & perform.	D	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D	D/E	D/E	D/E	E/D	E/D	D/E	E/D	D/E	D/E	D/E
Short-range communication *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GNSS positioning	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
HD map *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
C-ITS services	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

NEXT STEPS

- The Finnish Transport Infrastructure Agency has identified, based on the AUTOMOTO project and national and international collaboration, the needed actions to improve conditions for the automation of road transport

- The road owner and operator actions could be divided into three main categories
  I. study-type actions that are aimed at identifying the development needs of various processes and the related costs and timetables
  II. pilot and proof-of-concept projects where development actions are tested
  III. large scale implementation/deployment actions

- In the case of automated driving, priority is given to actions that could specifically **increase and extend the ODD of the automated driving systems**

- The actions will focus first on the motorway network, followed by main roads, and finally on the rest of the other road network

NEXT STEPS

Physical infrastructure and maintenance

- Identify current processes and necessary changes regarding the management, maintenance, and repair of the motorway environment
- The focus is on traffic control equipment (including road markings) and road pavement.
- The included maintenance actions are:
  - repair of the pavement defects
  - maintenance or renewal of traffic control equipment & road markings
  - maintenance of the road shoulder area
  - winter maintenance, including antiskid treatment and snow ploughing

- Process changes:
  - Define and plan
  - Pilot (in limited area)
  - Scale up and deploy

NEXT STEPS

Data

- Identify the most relevant/crucial static and dynamic datasets and their quality requirements for CCAM:
  - Digital model & digital twin
  - ITS Directive/RTTI delegated act
  - Digital traffic rules & regulations
- Regarding these datasets, identify:
  - current data production and management models
  - required accuracy and quality levels
  - possible existing quality shortcomings
- Specify process changes & do a cost-benefit analysis

- Process changes:
  - Define and plan
  - Pilot
  - Scale up and deploy

NEXT STEPS

Digital infrastructure (mobile & fixed networks)

- The actions will focus on studying the possibilities for the road owner and operator to support the development and deployment of mobile and fixed data networks, in particular from the perspective of automated traffic
- Permitting processes and guidelines for the installation of passive and active digital infrastructure in the road environment
- In addition, the criteria for mobile network “hot spots” and their potential locations on the road network will be studied

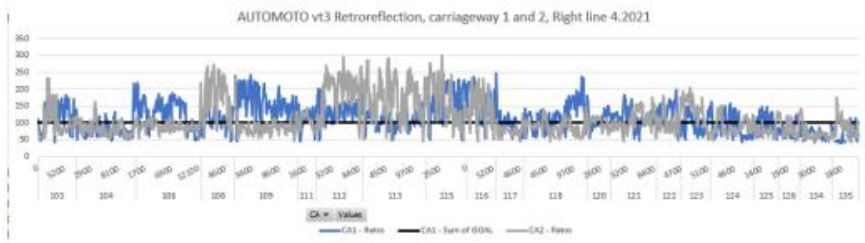
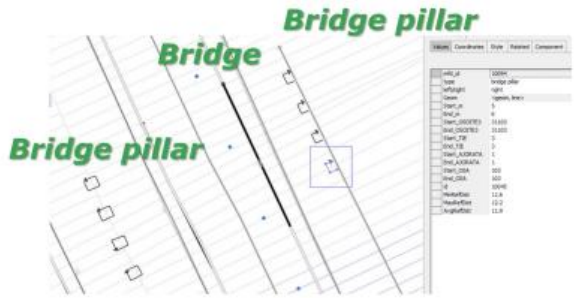


Figure 3. Right line, lane marking retroreflectivity, both carriageways, measurement data April 2021, vt 3 AUTOMO 2021 road sections



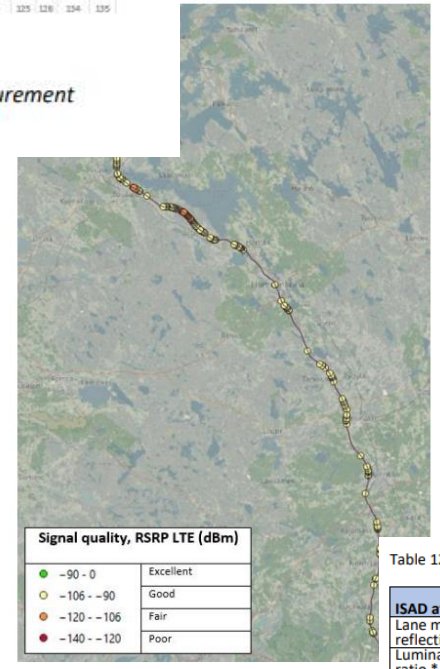


Figure 39. Tre-Hki, mobile network LTE measurements, RSRP <

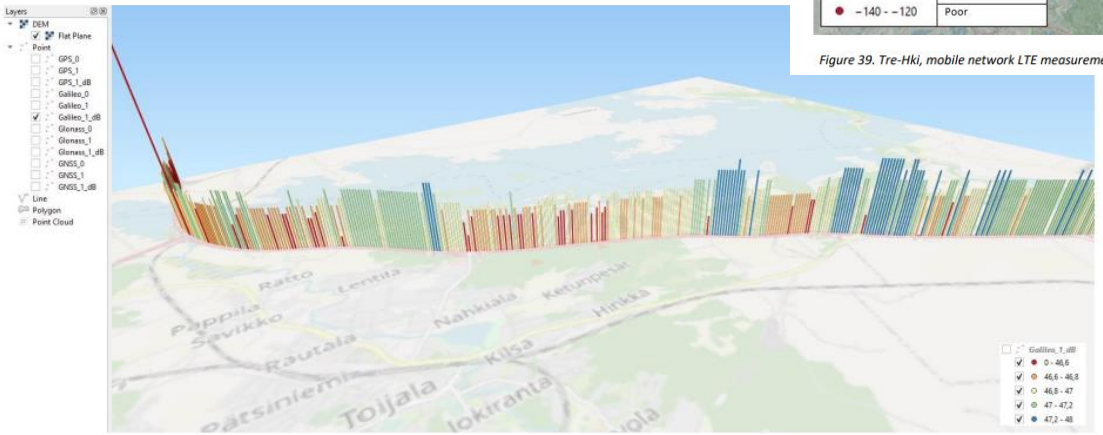
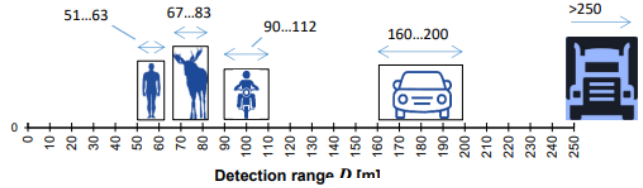


Figure 26. Galileo signal strength in Nahkialanvuori, Toijala (dB).



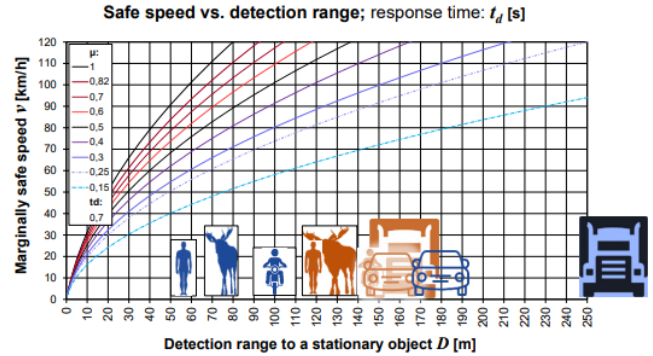


Figure 7 Radar (blue) and lidar (orange) detection ranges to the various objects analysed in this study, and safe stopping distance from different speeds with varying tyre-road friction coefficient. The delay t_d (see equation 2) from the first obstacle detection to the beginning of emergency braking is assumed to be 0.7 seconds.

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Bearing capacity of lane *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Shoulder width	C/E	C	C	C	C	C/E	E	E	E	E/C	C	C	C	C	C	C	C	C	C	C	C
Shoulder bearing capacity *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Widening or lay-by	D	D	D	D	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	E
Drivable area sign *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Induced road surface condition	<E	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	<E	D
Landmarks (here: lighting poles	C	D	D/C	D/C	D	D	D	D/C	D	C	D/C	D	D	D	D	D/C	D/C	D/C	D/C	D/C	C
Construction site detour *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Road works *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Communication cellular & perform.	D	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D/E	D	D/E	D/E	D/E	E/D	E/D	D/E	E/D	D/E	D/E	D/E
Short-range communication *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GNSS positioning	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
HD map *	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
C-ITS services	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

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Nordic WAY

Thank you!